Remarks addressing the Technical Design Report for the Upgrade to the ALICE Time Projection Chamber

The Technical Design Report for the Upgrade of the ALICE Time Projection Chamber provides a through and comprehensive description of the planned ALICE TPC upgrade. Their approach is sound in that it incorporates as much as possible the existing ALICE TPC structure.

There is the concern, however, as has been recognized by others, that the large space charge distortions to the electron drift path that result from back flow of positive ions from the readout chambers may be beyond the limit of correction methods. The ALICE plan outlined, focuses on the development of readout chambers which limit the ion back flow thus avoiding the need for the traditional gating grid. This is driven by the desire to operate at 50 kHz event rates where there is not sufficient time to close a traditional gating grid after each event to remove the positive ion back flow.

The authors have done significant analysis measuring the back flow currents, estimating positive ion densities in the TPC volume and investigated distortion correction approaches that actively monitor and corrector for fluctuations in the space charge density. This is necessary since the predicted distortions are as high as 20 cm and the position resolution requirements are on the 100 µm scale[1]. Space charge estimates have been based on actual measurements of current back flow from the readout GEM detectors planned for the TPC readout. However, these space charge density estimates have relied on assumptions that with their gas mixture of, Ne-CO_2-N_2, the positive ions are Ne^+ [2]. This assumption is likely incorrect because the ionization potential of CO_2 is lower than Ne, so one would reasonably expect that at atmospheric pressure in the low drift field region that Ne^+ formed in the ionization region of the GEMs would quickly transfer charge to the CO_2 molecules making CO_2^+ the majority ion in the drift volume of the TPC [3 4]. This in itself would not significantly change their analysis since the mobility of CO_2^+ in Ne is higher than Ne^+ in Ne. The real concern is that one does not actually know what the positive ions are. There could well be unknown contaminates with lower ionization potentials which end up carrying the charge and which have significantly lower mobilities [3, 4]. This would result in higher space charge fields. In STAR estimates of the primary ionization space charge density [5] have been compared with the density required to correct for the measured distortions. It was found that the estimates were a factor of 3 low compared to the density required for correction [6]. It could be that this discrepancy is due to slow contaminate based positive ions. Confidence in the ALICE space charge analysis would be improved if they could ID the positive ions.

The ALICE authors have determined that the back flow current from the readout GEM detectors is 1% of the avalanche generated current and that this produces 40 times the space charge generated by the primary ionization occurring in the main TPC drift volume [7]. They are looking for improvements in GEM design and configurations to reduce the back flow current, but it seems unlikely that dramatic gains will be made here. The readout system is already fairly complicated with 4 GEM layers. Considering the quantitative uncertainties in space charge and the difficulties in successfully correcting for the very large anticipated distortions it would be wise to consider alternative gating grid schemes that could completely remove the back flow ions. The following link presents a possible approach which would completely remove the back flow ions and would result in only a minor reduction in TPC live time: http://www-rnc.lbl.gov/~wieman/alice%20upgrade%20gating%20grid.pdf or original power point

http://www-rnc.lbl.gov/~wieman/alice%20upgrade%20gating%20grid.pptx

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[1] ALICE Collaboration, *Technical Design Report for the Upgrade of the ALICE Time Projection Chamber*, ALICE-TDR-016, March 3, 2014, p. ii.
[2] Ibid., p. 13.
[3] W. Blum and L. Rolandi, Particle Detection with Drift Chambers, Springer-Verlag, 1994, p. 62-65.
[4] E.W. McDaniel and E.A. Mason, The Mobility and Diffusion of Ions in Gases, John Wiley & Sons, 1973, p. 10,29,39,40.
[5] H. Wieman, http://www-rnc.lbl.gov/~wieman/TPC%20Rev%202006%20abrv%20for%20Ron.pdf
[6] E. Van Buren, Private Communication, 2014.
[7] ALICE Collaboration, *Technical Design Report for the Upgrade of the ALICE Time Projection Chamber*, ALICE-TDR-016, March 3, 2014, p. 86-88.